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Astronomers Chart the Unseen Between the Stars

By DENNIS OVERBYE

There is more than one way to see the universe, and some of them were featured this month in Sydney, Australia, where the world's astronomers gathered for the triennial meeting of the International Astronomical Union.

Once restricted to looking at the pearly lights of stars, astronomers have increasingly sought to look for what they cannot see in the darkness between the stars.

Some have used a chunk of Antarctica as their telescope to map the rain of high-energy particles from the cosmos.

Others have used galaxies themselves as lenses to limn invisible clouds of dark matter that envelop the cosmos.

And still others are using a giant telescope of the conventional kind to peel away cosmic history like the layers of an onion, producing a snapshot of the universe at earlier times, when it was assembling itself into the knotted chains of galaxies that now wreath the night.

About a mile below the South Pole, 677 bowling-ball-size detectors known collectively as the Amanda II telescope record the rare flashes of light produced when the exotic ghostlike particles known as neutrinos scream through the ice.

In Sydney, Amanda astronomers, led by Dr. Francis L. Halzen of the University of Wisconsin, showed off the first rough map of the neutrino sky.

Neutrinos are among the most mysterious creatures in nature. Produced in abundance in supernova explosions, nuclear reactions and the Big Bang, they are nearly massless, move at almost the speed of light and can pass through miles of lead with impunity.

Indeed, to screen out interference from ordinary cosmic rays, Amanda detectors point not up at the sky, but downward, to record cosmic neutrinos coming up through the Earth from the other side of the sky.

The resultant map, based on a year's worth of data, shows the northern sky more or less evenly speckled with neutrino sources. Most of those, Dr. Halzen said, are low-energy neutrinos produced when cosmic rays, mostly atomic nuclei flying through the space from the Sun and elsewhere, strike the atmosphere.

To find neutrinos from deep space, he said, the scientists would look for clustering on the map or very high energies. Such observations may eventually be a road map to the locations of high-energy catastrophes like exploding stars or black holes crashing that have somehow ramped up some neutrinos to energies 100 times as

great as any that have been produced in earthbound particle accelerators.

"This map could hold the first evidence of a cosmic accelerator," Dr. Halzen said. "But we are not there yet."

The main significance of the map, he and others said, is that it shows that the technique works, paving the way for a larger array known as IceCube, which will equip a cubic kilometer of ice with 5,000 detectors. In an e-mail message, Dr. John G. Learned, a physicist at the University of Hawaii, said, "It is most important in demonstrating that IceCube will work."

A similar invisibility cloaks the so-called dark matter, perhaps clouds of exotic slow-moving elementary particles left over from the Big Bang, which seems to swaddle galaxies and, perhaps, provides the scaffolding for cosmic structures.

But astronomers were recently able to construct the most detailed map ever made of the dark matter in a cluster of galaxies, an assemblage known as CL0024+1654 about 4.5 billion light-years away, by measuring the distortion caused by the cluster's gravity on the light passing through from distant galaxies.

According to Einstein's general theory of relativity, the dark and luminous matter should bend the light like a lens, twisting the shapes of more distant galaxies. To map the cluster, an international team led by Dr. Jean-Paul Kneib of the California Institute of Technology and the Mid-Pyrenees Observatory in France, took 40 photographs totaling 120 hours of exposure with the Hubble Space Telescope, one of the largest blocks of Hubble time ever devoted to a single celestial object.

The map, the team said, shows that the luminous and dark matter, at least in this cluster, are tightly connected, reinforcing the theorists' view that it is the dark matter, falling into larger and larger clouds that provide the gravitational glue to hold galaxies and clusters of galaxies together.

Within the cloud are distinct knots and lumps, each one corresponding to smaller clumps of galaxies that are falling into the cluster, said Dr. Richard S. Ellis of Caltech, another team member. Dr. Ellis compares the cluster to a cake made of lumpy dough that is the dark matter. The luminous matter, he said, is like icing.

"The frosting follows the lumps very accurately," he said.

This process of organization and cosmic evolution has been caught in action by yet another team of astronomers that is using the 10-meter-diameter Keck II telescope on Mauna Kea, Hawaii, to study galaxies as they existed seven billion years ago, when the universe was half its age.

The first results from the survey were released in Sydney as maps of the locations of distant galaxies in three small patches of sky studied by the Keck telescope. The maps show that galaxies back then were less tightly clustered in groups and chains than they are today, the astronomers said.

"We've seen evolution in clustering," said Dr. Sandra M. Faber of the University of California at Santa Cruz, adding that is further confirmation of the hierarchical "bottom-up" model of structure formation favored by theorists.

Dr. Faber is a leader of the team known as DEEP2 that is also led by Dr. Marc Davis of the University of California at Berkeley and includes astronomers from other institutions. By the time the three-year project is completed, the scientists expect to have measured 60,000 galaxies to a distance of nine billion light-years.

This is the first time, Dr. Faber said, that astronomers have been able to look at "normal objects," which can be compared to galaxies today, at that distance.

Another intriguing result, she said, is that red galaxies seem to be more clustered and organized than blue ones in the early universe. Reddish galaxies are red because they are filled with old stars and have ceased making new blue ones. The fact that they already existed when the universe was half its age raises the question of exactly how and when they shut down making stars so early.

One speculative possibility, Dr. Faber suggested, is that the huge black holes that anchor the cores of such galaxies blew all the gas and dust out of them early on, depriving the galaxy in perpetuity of the stuff for new stars.

"The black hole itself," she said, "blows out the galaxy."